RESEARCH MEMORANDUM

LONGITUDINAL CHARACTERISTICS OF AN UNSWEPT-WING FIGHTER-TYPE MODEL WITH EXTERNAL STORES AT A MACH NUMBER OF 1.82 AND SOME EFFECTS OF HORIZONTAL-TAIL AND YAW-DAMPER-VANE DEFLECTION ON THE SIDESLIP DERIVATIVES

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel to determine the effects of the addition of one body-mounted external store, tip tanks, and several tip-mounted missile configurations on the aerodynamic characteristics in pitch of a fighter model with a low-aspect-ratio, unswept wing at a Mach number of 1.82. Limited tests were also made to obtain the interference effects of horizontal-tail deflection on the sideslip derivatives, the control characteristics of a yaw-damper vane, and the effects of a ventral fin on the longitudinal characteristics.

The results indicated that the addition of any of the tip-mounted store configurations to the basic model produced increased lift-curve slopes and drag increments which decreased with increasing lift coefficient above lift coefficients of about 0.06. The body-mounted store caused no change in the lift-curve slope of the basic model and resulted in drag increments that increased with increasing lift coefficients. Of all the store configurations tested, the external store arrangement causing the least drag increment was the tip-mounted Sidewinder missile configuration.

Negative deflection of the high horizontal tail decreased the directional stability and produced a smaller value of positive effective dihedral.

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INTRODUCTION

Until recently there has been only a limited amount of experimental information on the aerodynamic characteristics of airplane configurations with low-aspect-ratio, unswept wings at supersonic speeds. The results of wind-tunnel tests to investigate various horizontal- and vertical-tail configurations of a fighter model having a low-aspect-ratio, unswept wing at Mach numbers of 1.35 to 1.90 are presented in references 1 and 2.

Among the problems of concern is the effect of the addition of external stores to unswept-wing aircraft at these Mach numbers. This report presents the results of an investigation to determine the effects of various external store and missile configurations on the aerodynamic characteristics in pitch at a Mach number of 1.82 of a fighter model with a low-aspect-ratio, unswept wing. Limited data are also given for the effects of a ventral fin on the longitudinal characteristics, for the effects of stabilizer deflection on the sideslip derivatives, and for the control characteristics of a yaw-damper vane. The tests were made in the Langley 4- by 4-foot supersonic pressure tunnel at a Reynolds number of 2.03×10^6, based on the mean geometric chord of the wing.

COEFFICIENTS AND SYMBOLS

The results of this investigation are presented as standard NACA forces and moments. The lift, drag, and pitching-moment coefficients are referred to the stability axis system and the side-force, rolling-moment, and yawing-moment coefficients are referred to the body axis system with the reference center of gravity at 25 percent of the wing mean geometric chord (fig. 1). The coefficients and symbols are defined as follows:

C_L lift coefficient, F_L/qS

C_D' approximate drag coefficient, F_D'/qS

C_m pitching-moment coefficient, $M_Y/qS\bar{c}$

C_Y side-force coefficient, F_Y/qS

C_l rolling-moment coefficient, M_X/qSb

C_n yawing-moment coefficient, M_Z/qSb

F_D' drag (approximate), true drag at zero sideslip

F_Y side force

F_L lift

M_X moment about body X-axis

M_Y moment about stability Y-axis

M_Z moment about body Z-axis

q free-stream dynamic pressure

S total projected wing area including body intercept, 1.41 sq ft

b panel wing span, 22.50 in.

$\bar{c}$ wing mean geometric chord, 9.59 in.

M Mach number

α angle of attack of fuselage reference line, deg

β angle of sideslip of fuselage reference line, deg

i_t stabilizer incidence angle with respect to fuselage reference line, deg, positive trailing edge down

δ_V yaw-damper angle with respect to fuselage reference line, deg, positive trailing edge left

ΔC_D incremental drag due to addition of stores to the basic configuration

L/D lift-drag ratio

$C_{l_\beta} = \frac{dC_l}{d\beta}$ effective dihedral parameter

$C_{n_\beta} = \frac{dC_n}{d\beta}$ directional stability parameter

MODEL AND APPARATUS

A three-view drawing of the basic configuration and the ventral fin is presented in figure 2. Sketches of the various store configurations are shown in figure 3. Photographs of several configurations are presented in figure 4. Geometric characteristics of the model and of the various stores are given in tables I and II.

The model was equipped with a wing having 18.5° sweep of the 0.25 chord line, aspect ratio 2.45, taper ratio 0.377, and 3.4-percent-thick modified biconvex airfoil sections. The wing was set at zero incidence to the fuselage reference line and had 10° of negative geometric dihedral. The fuselage was contoured to simulate faired side inlets.

Deflections of the stabilizer and yaw damper were set manually. The rudder deflection was zero degrees for all the tests.

The ventral fin was a thin aluminum plate with beveled edges fastened to the bottom of the body. The base of the fin was faired to approximate body contour. The yaw damper was a trailing-edge flap located below the rudder on the vertical tail (fig. 2).

External store arrangements investigated were: (a) a pylon-mounted body store (fig. 3(a)); (b) two fuel tanks, one on each wing tip (fig. 3(b)); (c) two Sidewinder missiles with mounts, one on each wing tip, (fig. 3(c)); (d) two Falcon missiles with mounts, one on each wing tip (fig. 3(d)); and (e) four Falcon missiles, two per wing tip, on end-plate-type mounts (fig. 3(e)).

Force and moment measurements were made through the use of a six-component internal strain-gage balance. Base static pressures were measured just inside the model base.

TEST CONDITIONS AND PROCEDURE

The conditions for the tests were:

Mach number	1.82
Reynolds number, based on $\bar{c}$	2.03×10^{6}
Stagnation dewpoint, $^{\circ}F$	-20
Stagnation pressure, lb/sq in., abs	10
Stagnation temperature, $^{\circ}F$	100
Mach number variation	± 0.01
Flow angle in horizontal or vertical plane, deg	± 0.1

Tests were made through an angle-of-attack range of about -3° to about $+10^{\circ}$ at a sideslip angle of 0° and through an angle-of-sideslip range of about -3° to about 11° at an angle of attack of 5.2°. All tests were made with simulated faired side inlets. The effects of these fairings on the aerodynamic characteristics are not known but are believed to be small.

CORRECTIONS AND ACCURACY

The angle of attack and sideslip were corrected for the deflection of the balance and sting under load. No corrections were applied to the data to account for the tunnel flow variations. The drag data were adjusted by equating the base pressure to the free-stream static pressure.

Maximum probable errors in the data are:

C_L	± 0.0066
C_D'	± 0.0003
C_m	± 0.0007
C_l	± 0.0003
C_n	± 0.0001
C_Y	± 0.0019
α, β, i_t, δ_r, deg	± 0.1

RESULTS AND DISCUSSION

Effects of Various External Stores on the Aerodynamic Characteristics in Pitch

The aerodynamic characteristics in pitch for the basic configuration for $i_t = 0^{\circ}$ are shown in figure 5. The flagged symbols are data from a repeat run. The values of lift-curve slope and static longitudinal stability agree closely with the results shown in reference 1 for a similar configuration.

The effects of various store installations on the aerodynamic characteristics in pitch for $i_t = 0^{\circ}$ are presented in figure 6. Incremental drag coefficients for the various stores and the effects of the stores on lift-drag ratios are presented in figures 7 and 8, respectively. Addition of the body store produced larger incremental drag and lower lift-drag ratios throughout the positive lift range than any of the tip-mounted stores (figs. 7 and 8). All of the tip-mounted stores acted both as wing end plates and additional lifting surfaces, producing higher lift-curve slopes and decreasing drag increments with increasing lift coefficient above $C_L \approx 0.06$ (figs. 6(b) to 6(e), and fig. 7). Addition of the body-store configuration produced a slight shift in the lift curve with no change in lift-curve slope and indicated slightly increasing incremental drag with increasing lift (fig. 6(a)).

The static longitudinal stability and trim lift coefficients were practically the same for all configurations except for the body-store arrangement which had slightly greater stability and higher trim C_L than the basic model (fig. 6(a)) and the configuration with four tip-mounted Falcons which had somewhat less stability and a significantly smaller value of trim C_L than the basic model (fig. 6(e)). Of all the arrangements tested, the configurations with two Sidewinders and the two Falcons resulted in the smallest drag increments and the highest lift-drag ratios through the C_L range tested (figs. 7 and 8). Addition of two tip tanks or four Falcons to the basic configuration produced about the same drag increments and lift-drag ratios.

Although no sideslip tests were made for the configurations having external stores, some tests of a similar configuration at $M = 2.01$ (results unpublished) indicate that rather large decreases in directional stability might be anticipated for the body-mounted-store arrangement because of the forward position of the store relative to the airplane center-of-gravity location.

Effect of Ventral Fin on Aerodynamic Characteristics in Pitch

A previous investigation (results unpublished) of the directional characteristics of a similar configuration showed that a ventral fin materially increased the directional stability at high angles of attack. Model scale and instrumentation limitations did not permit evaluation of the effects of the fin on the longitudinal characteristics of this similar configuration. Addition of the fin to the present larger scale model indicated little effect on the aerodynamic characteristics in pitch except for an increase in C_D' of about 0.0010 (fig. 9).

Effect of Stabilizer Deflection on Aerodynamic Characteristics in Sideslip

A -8° deflection of the horizontal stabilizer of the basic model at $\alpha = 5.2^{\circ}$ (fig. 10) produced a reduction in both the directional stability $\left(C_{n_{\beta}}\right)$ and positive effective dihedral $\left(-C_{l_{\beta}}\right)$. These effects probably result from the reduction of the positive pressures on the high-pressure surface of the vertical tail in the region of the negative pressures propagated from the bottom surface of the horizontal tail. Unpublished results of tests of a swept high horizontal-vertical tail arrangement at $M = 2.01$ indicate the same effect, while other tests have shown that negative deflections of a low stabilizer have the opposite effects.

It might also be expected that deflections of the horizontal tail would cause changes in the rudder control characteristics, but sufficient tests were not made to determine this.

Effect of Deflection of the Yaw Damper

Deflecting the yaw damper -20° resulted in a practically constant increment of yawing-moment coefficient of about 0.0025 and a slightly negative increment in side-force coefficient throughout the angle-of-attack range investigated (fig. 11). Since the damper was below the rudder (fig. 2) and had both a small area and short moment arm with respect to the fuselage reference line, the values of rolling-moment coefficient produced were small.

CONCLUSIONS

An investigation of the effects of external stores, ventral fin drag, some horizontal-tail interference effects, and a yaw-damper control on an unswept-wing, fighter-type model at a Mach number of 1.82 has indicated the following conclusions:

1. The addition of any of the tip-mounted store configurations to the basic model produced increased lift-curve slopes and, for lift coefficients greater than about 0.06, drag increments which decreased with increasing lift coefficients. The body-mounted store caused no change in the lift-curve slope of the basic body and produced drag increments which increased slightly with increasing lift.

2. The addition of the Sidewinder missile configuration to the basic model produced the smallest drag increments and highest lift-drag ratios for any combination tested. The largest drag increments resulted from the addition of the body-store arrangement.

3. Negative deflection of the high horizontal stabilizer of the basic model resulted in decreased directional stability and a smaller value of positive effective dihedral.

4. A yaw-damper deflection of -20° produced a practically constant increment of yawing-moment coefficient of about 0.0025 through the lift-coefficient range tested for the basic model.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 5, 1955.

REFERENCES

1. Smith, Willard G.: Wind-Tunnel Investigation at Subsonic and Supersonic Speeds of a Fighter Model Employing a Low-Aspect-Ratio Unswept Wing and a Horizontal Tail Mounted Well Above the Wing Plane - Longitudinal Stability and Control. NACA RM A54D05, 1954.

2. Wetzel, Benton E.: Wind-Tunnel Investigation at Subsonic and Supersonic Speeds of a Fighter Model Employing a Low-Aspect-Ratio Unswept Wing and a Horizontal Tail Mounted Well Above the Wing Plane - Lateral and Directional Stability. NACA RM A54H26b, 1955.

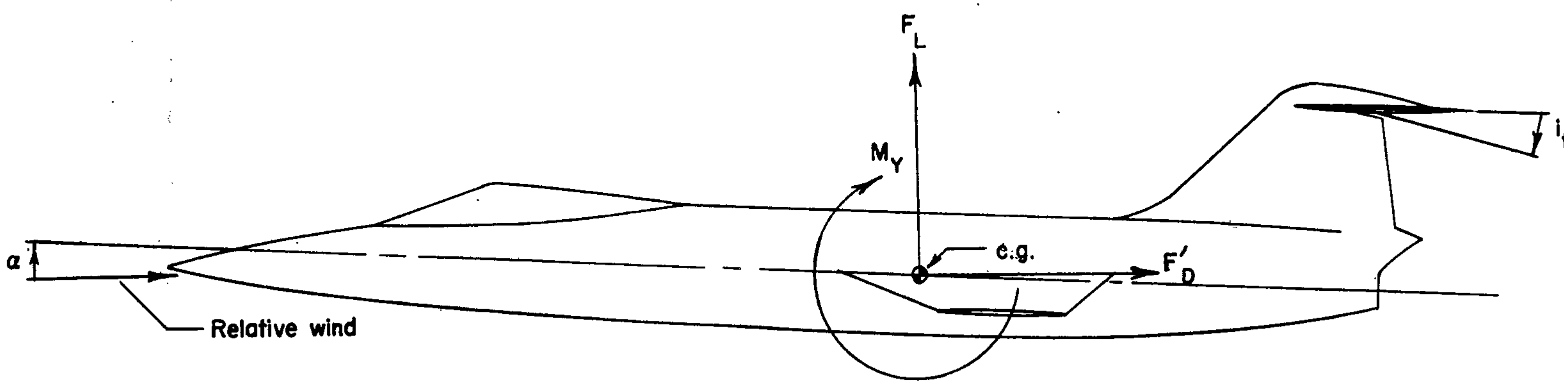
TABLE I.- GEOMETRIC CHARACTERISTICS OF MODEL

Wing:	
Airfoil section - modified biconvex, 3.4-percent thick, forward 0.5 chord elliptical; rear 0.5 chord circular arc	
Total projected area (including fuselage intercept), sq ft	1.41
Mean geometric chord, in.	9.59
Span, projected, in.	22.31
Aspect ratio	2.45
Root chord, in.	13.24
Tip chord, in.	5.00
Taper ratio	0.377
Incidence, deg	0
Dihedral, deg	-10
Sweep of 0.25 chord, deg	18.5
Sweep of leading edge, deg	27.45
Horizontal tail:	
Airfoil section:	
Root - modified biconvex (see wing)	5 percent thick
Tip - modified biconvex (see wing)	3 percent thick
Total area, sq ft	0.356
Mean geometric chord, in.	4.54
Span, in.	12.33
Aspect ratio	2.96
Root chord, in.	6.34
Tip chord, in.	1.97
Taper ratio	0.312
Tail length (0.25 wing mean geometric chord to 0.25 horizontal tail mean geometric chord), in.	17.24
Sweep of 0.50 chord, deg	0
Sweep of leading edge, deg	19.85
Vertical tail:	
Airfoil section:	
Root - modified biconvex (see wing)	4.25 percent thick
Tip - modified biconvex (see wing)	5 percent thick
Exposed area, sq ft	0.2231
Mean geometric chord of exposed area, in.	7.12
Span (exposed), in.	5.66
Aspect ratio	0.997
Root chord, 2.32 in. above body axis, in.	9.65
Tip chord, 7.98 in. above body axis, in.	4.46
Taper ratio	0.463
Sweep of 0.25 chord, deg	34.77
Tail length (0.25 wing mean geometric chord to 0.25 vertical tail mean geometric chord), in.	13.52
Yaw damper:	
Area, sq ft	0.0077
Length, in.	1.01
Fuselage:	
Length, in.	47.62
Maximum frontal area, sq ft	0.154
Base area, sq ft	0.035

TABLE II.- DETAILS OF EXTERNAL STORES

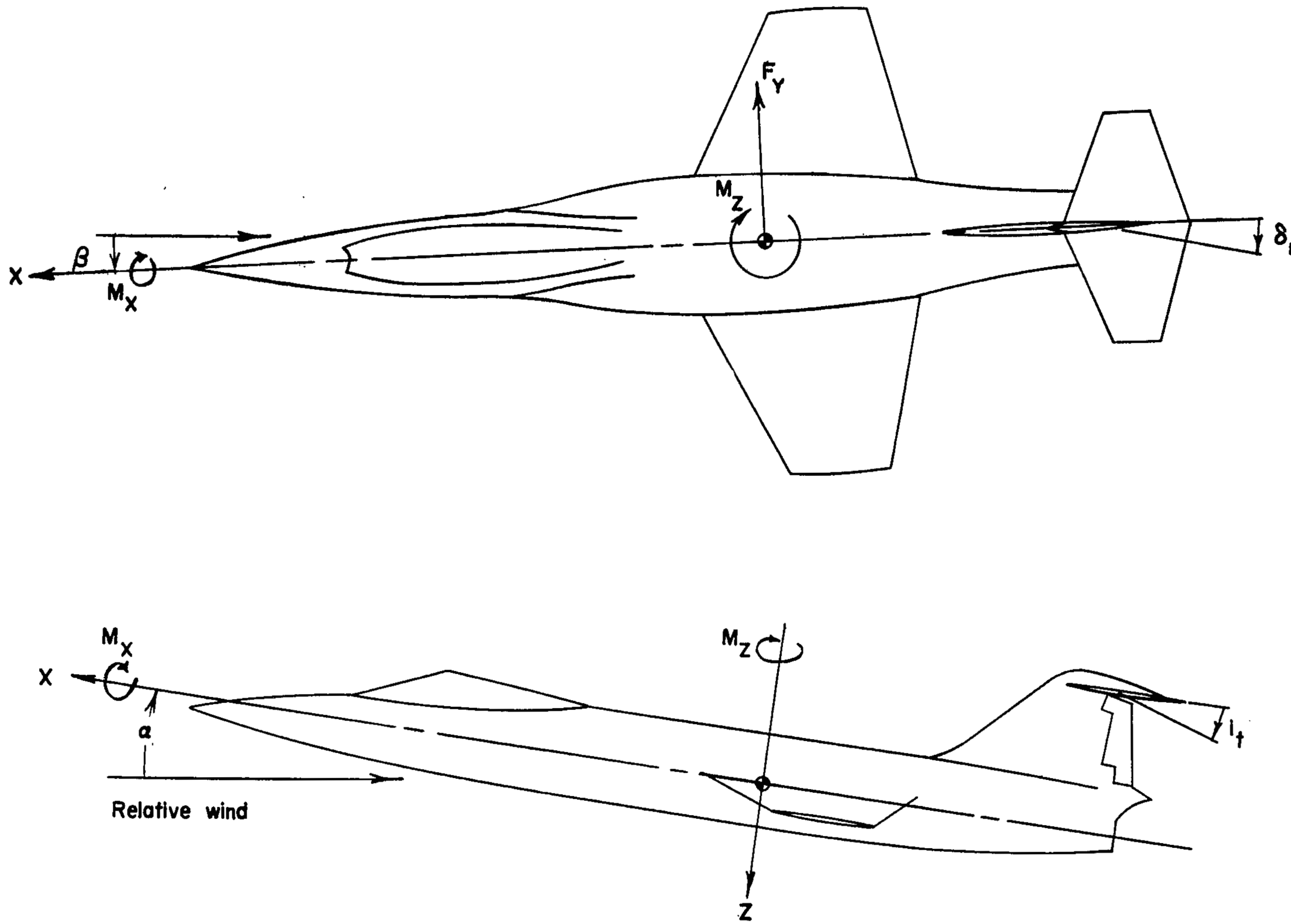
Wing tip tanks:	
Length, in.	18.3
Maximum diameter, in.	1.72
Maximum frontal area, each, sq ft	0.016
Length-diameter ratio	10.67
Nose at fuselage station, in.	22.22
Center line at wing station, in.	11.56
Sidewinder missile and mount:	
Missile (each):	
Length, in.	9.38
Maximum diameter, in.	0.47
Maximum frontal area, sq ft	0.00194
Wetted area, sq ft	0.1438
Length-diameter ratio	19.88
Nose at fuselage station, in.	25.56
Center line at wing station, in.	11.76
Incidence of center line to fuselage reference line, deg	0
Mount (each):	
Length, in.	9.22
Maximum frontal area, sq ft	0.00076
Wetted area, sq ft	0.064
Leading edge at fuselage station, in.	25.70
Falcon missile and mount (two per wing tip):	
Missile (each):	
Length, in.	6.40
Maximum diameter, in.	0.55
Maximum frontal area, sq ft	0.00277
Wetted area, sq ft	0.207
Length-diameter ratio	11.63
Nose at fuselage station, in.	29.85
Center line at wing station, in.	11.43
Height of missile center line above and below wing reference plane, in.	0.94
Incidence of center line to fuselage reference line, deg	0
Mount (each):	
Length, in.	11.94
Maximum frontal area, sq ft	0.00245
Wetted area, sq ft	0.391
Center line at wing station, in.	11.43
Leading edge at fuselage station, in.	27.45
Missile and mount (each):	
Maximum frontal area, sq ft	0.00522
Maximum wetted area, sq ft	0.598
Fuselage store and mount:	
Store alone:	
Length, in.	13.30
Maximum diameter, in.	1.88
Maximum frontal area, sq ft	0.0213
Wetted area, sq ft	0.559
Length-diameter ratio	7.07
Nose at fuselage station, in.	17.12
Incidence of center line to fuselage reference line, deg	0.50
Mount alone:	
Length, in.	5.23
Maximum frontal area, sq ft	0.0024
Wetted area, sq ft	0.0703
Leading edge at fuselage station, in.	20.55
Store and mount:	
Maximum frontal area, sq ft	0.0224
Wetted area, sq ft	0.594
Falcon missile and mount (one per wing tip)[1]:	
Nose at fuselage station, in.	26.29
Center line at wing station, in.	12.11
Height of missile center line from wing chord plane, in.	0
Mount leading edge at fuselage station, in.	26.54

[1]All other dimensions of the missile are those of the "two per wing tip" arrangement.



(a) Stability axis system.

Figure 1.- Axis systems. Arrows indicate positive direction.



(b) Body axis system.

Figure 1.- Concluded.

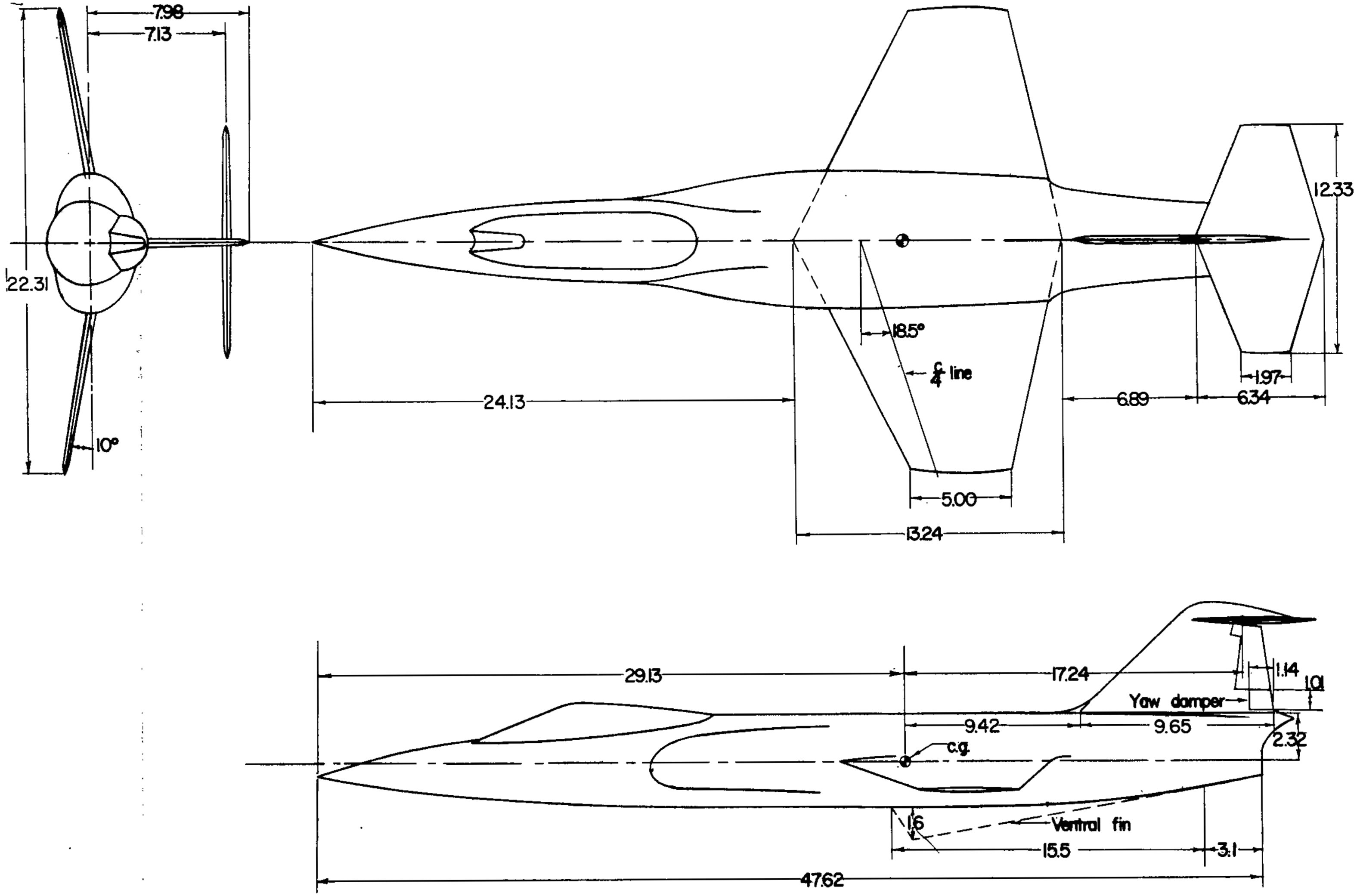
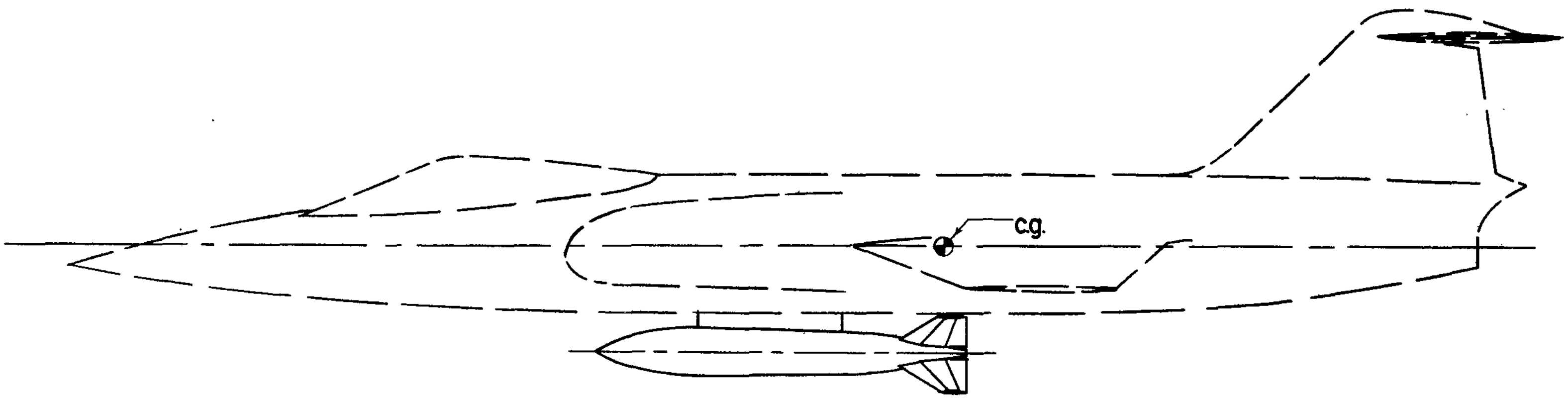
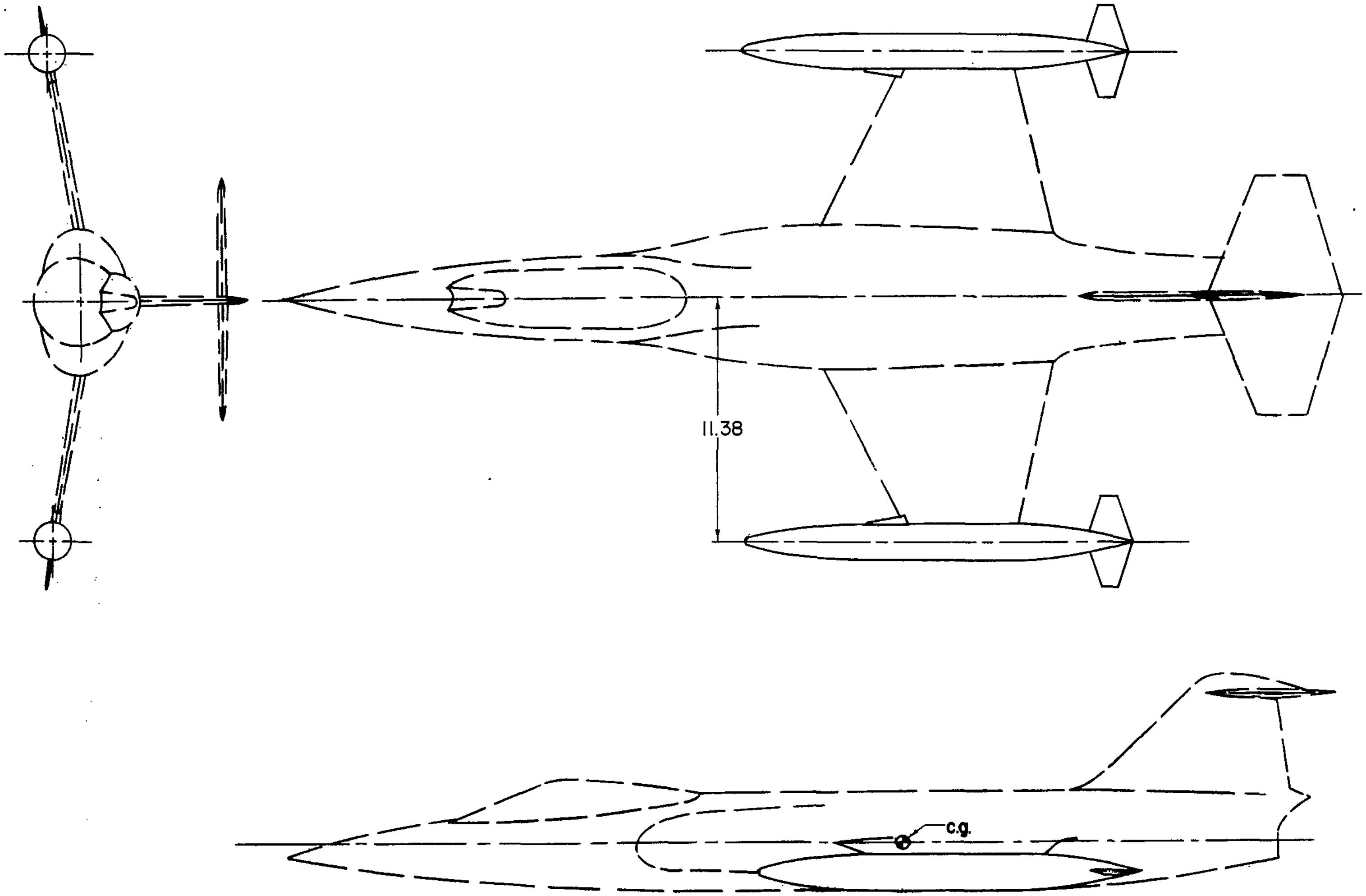


Figure 2.- Sketch of model. All dimensions are in inches except as noted.



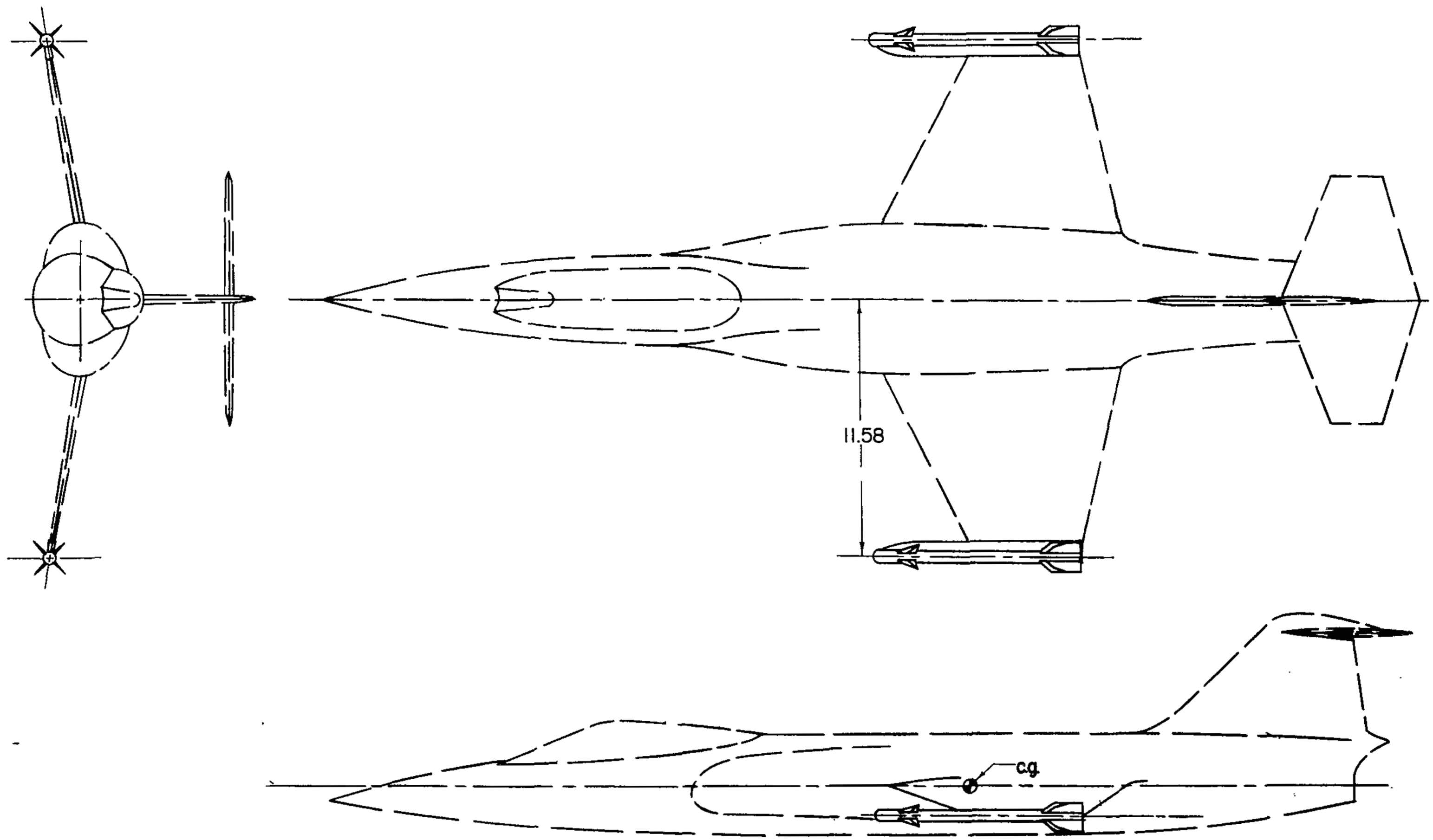
(a) Body store.

Figure 3.- Sketches of external-store configurations. See table I for dimensions.



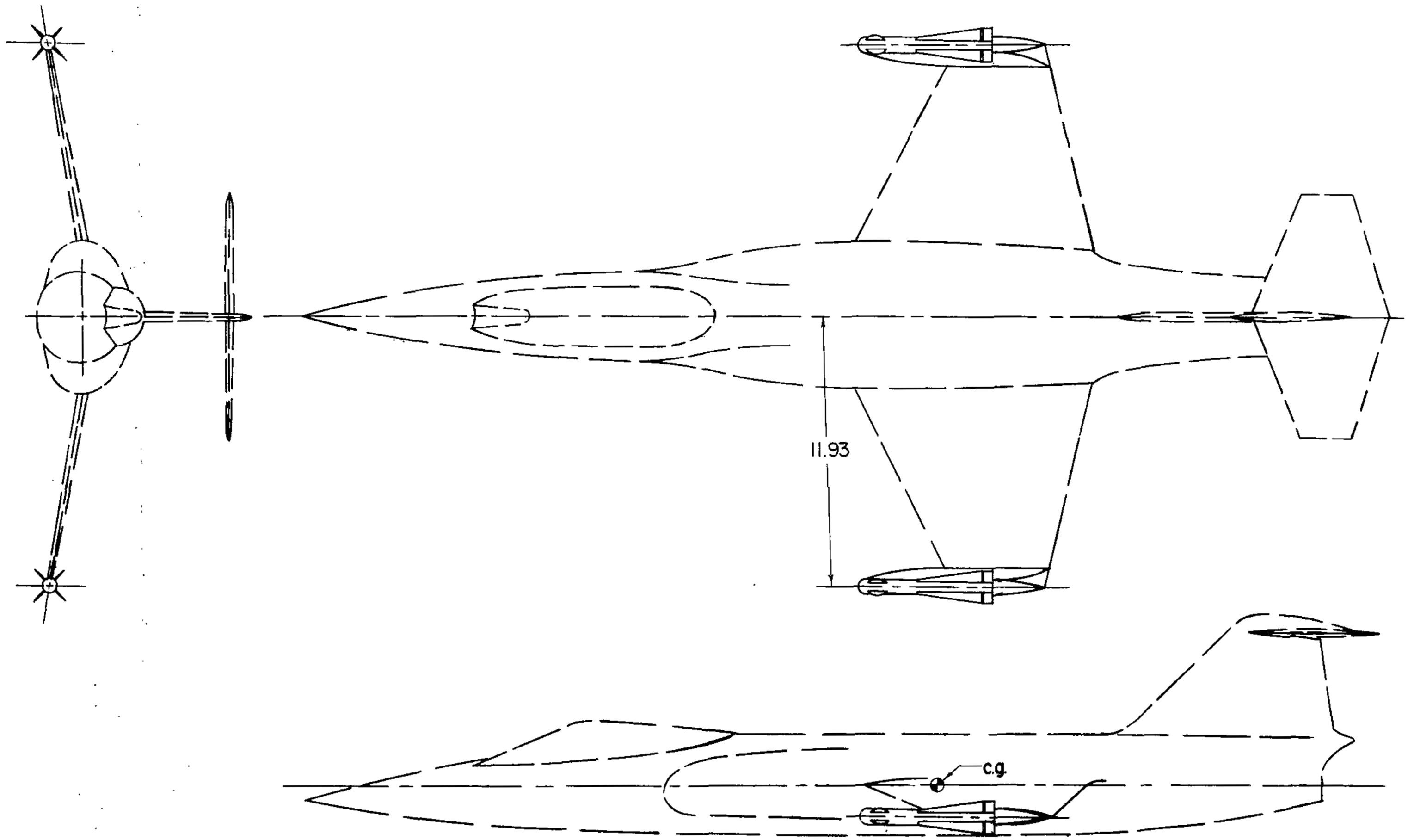
(b) Tip tanks.

Figure 3.- Continued.



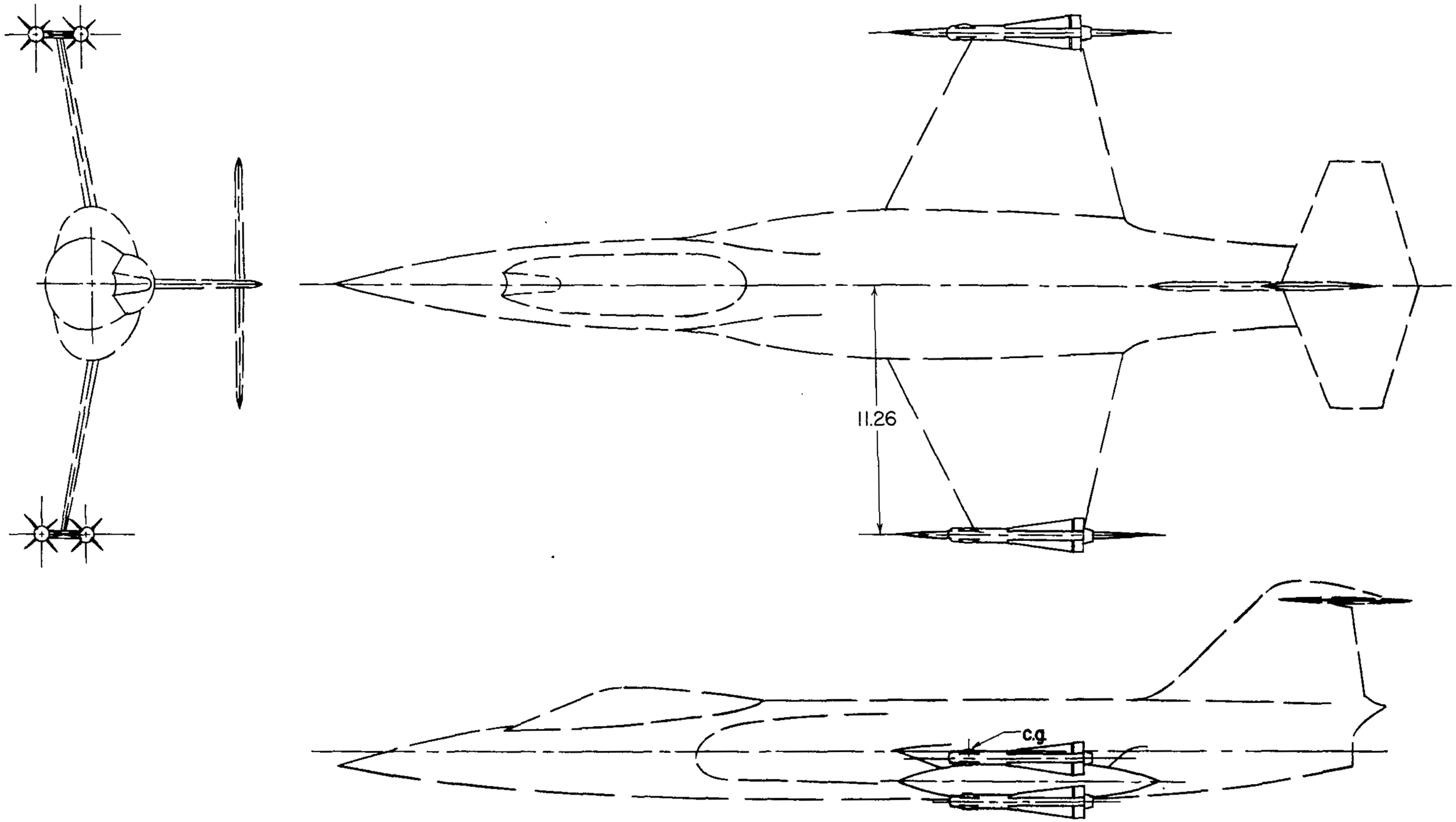
(c) Two tip-mounted Sidewinder missiles.

Figure 3.- Continued.



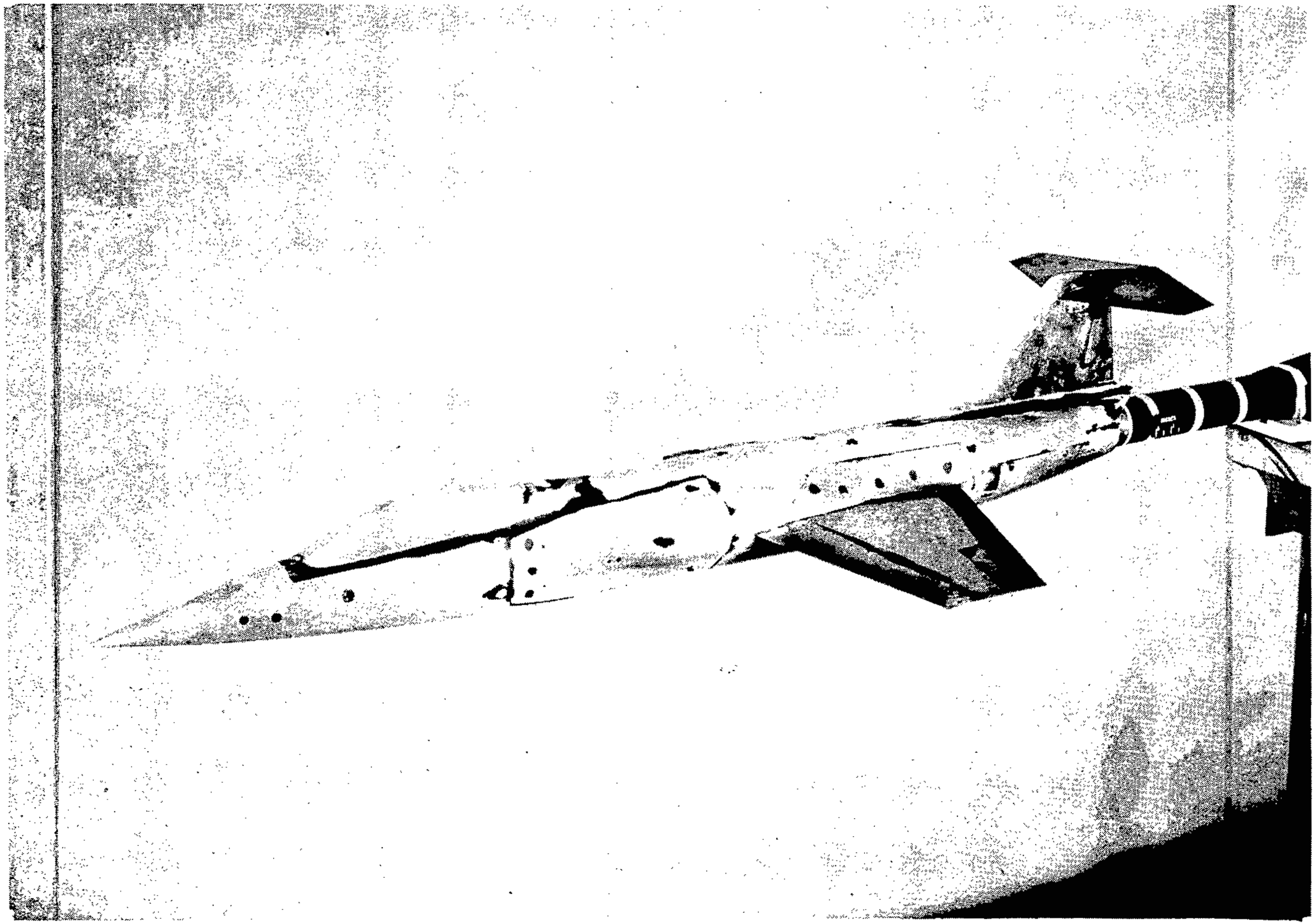
(d) Two tip-mounted Falcon missiles.

Figure 3.- Continued.



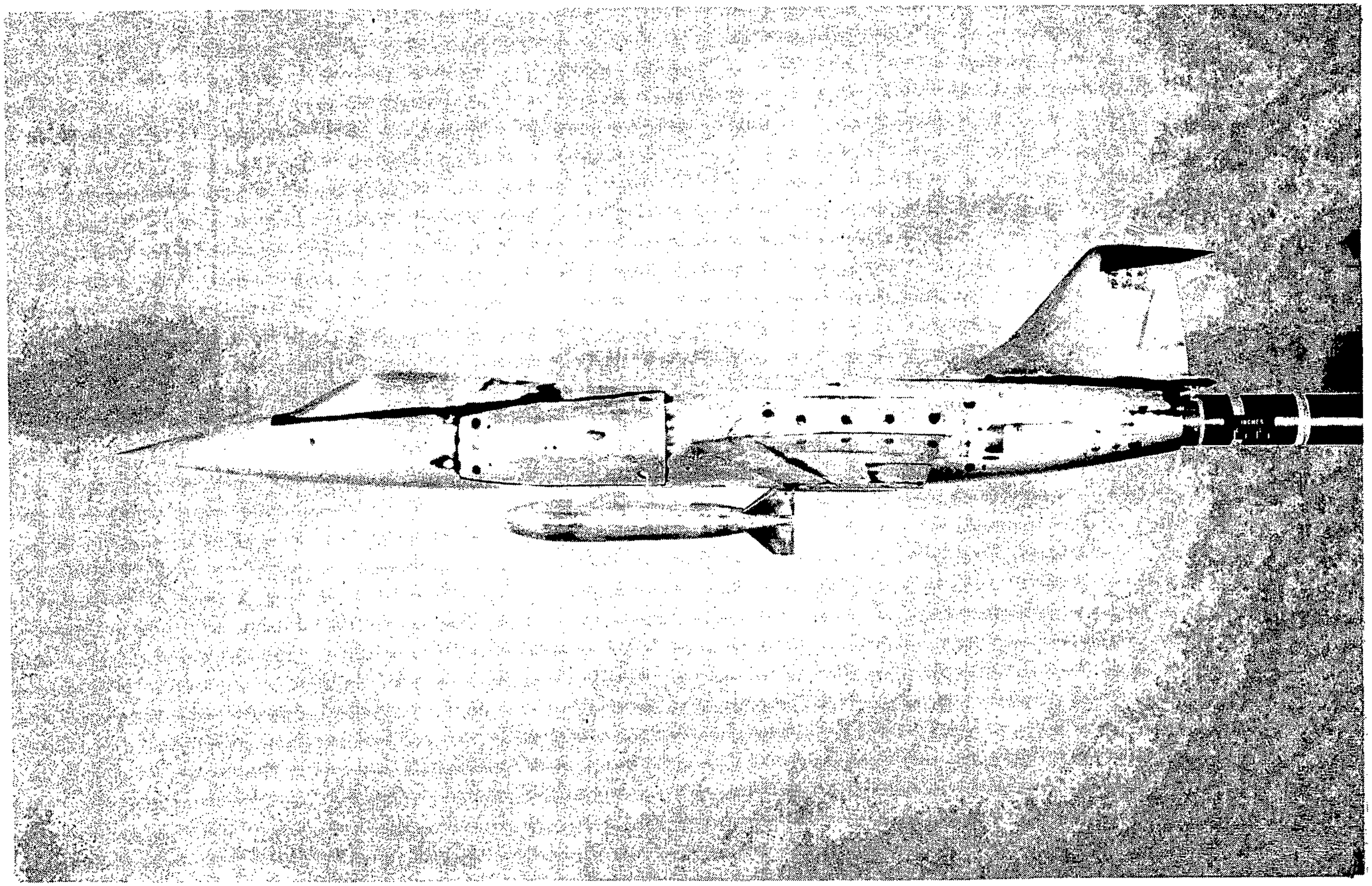
(e) Four tip-mounted Falcon missiles.

Figure 3.- Concluded.



(a) Basic model. L-89747

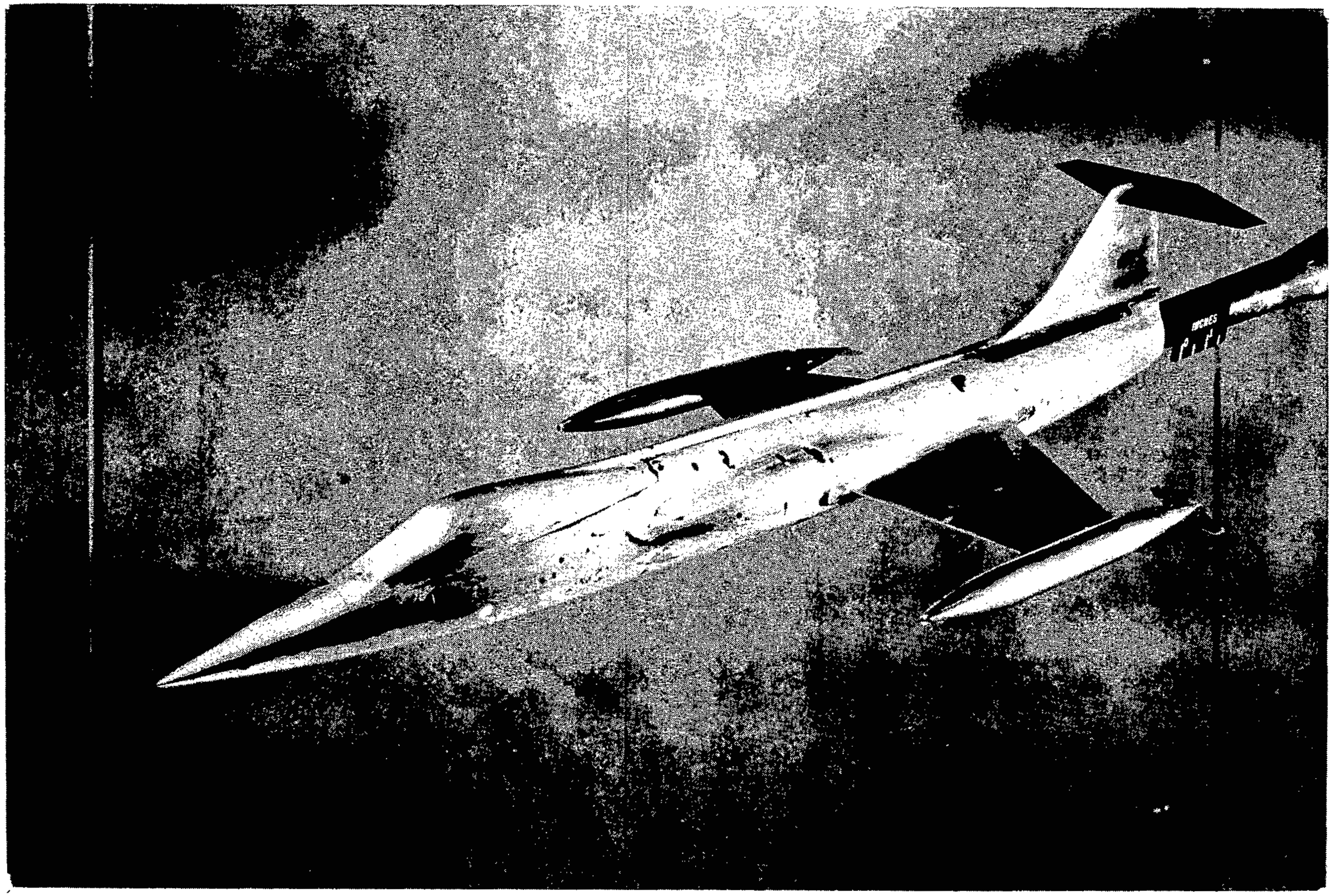
Figure 4.- Photographs of model.



L-89744

(b) Body store.

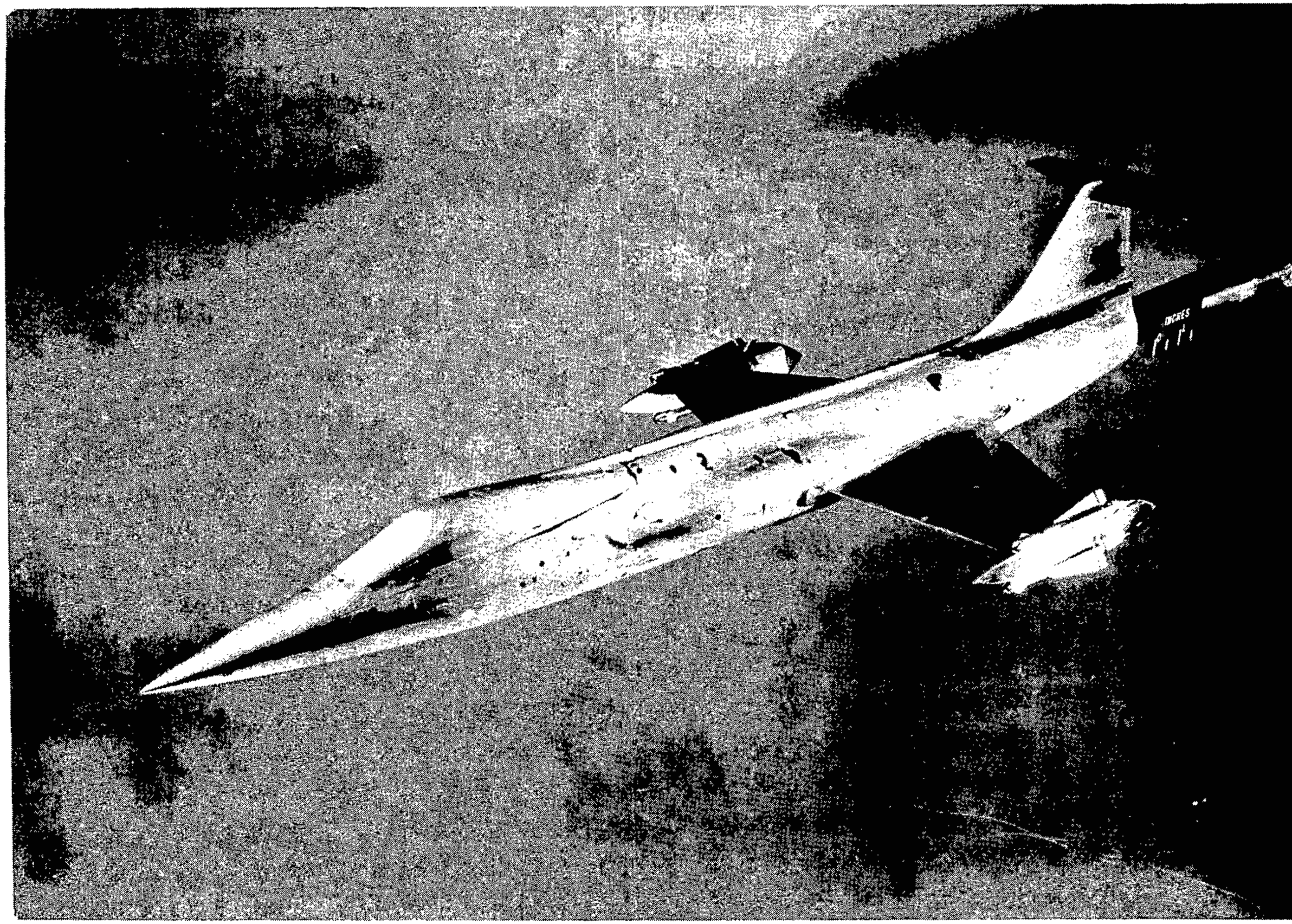
Figure 4.- Continued.



L-89749

(c) Tip tanks.

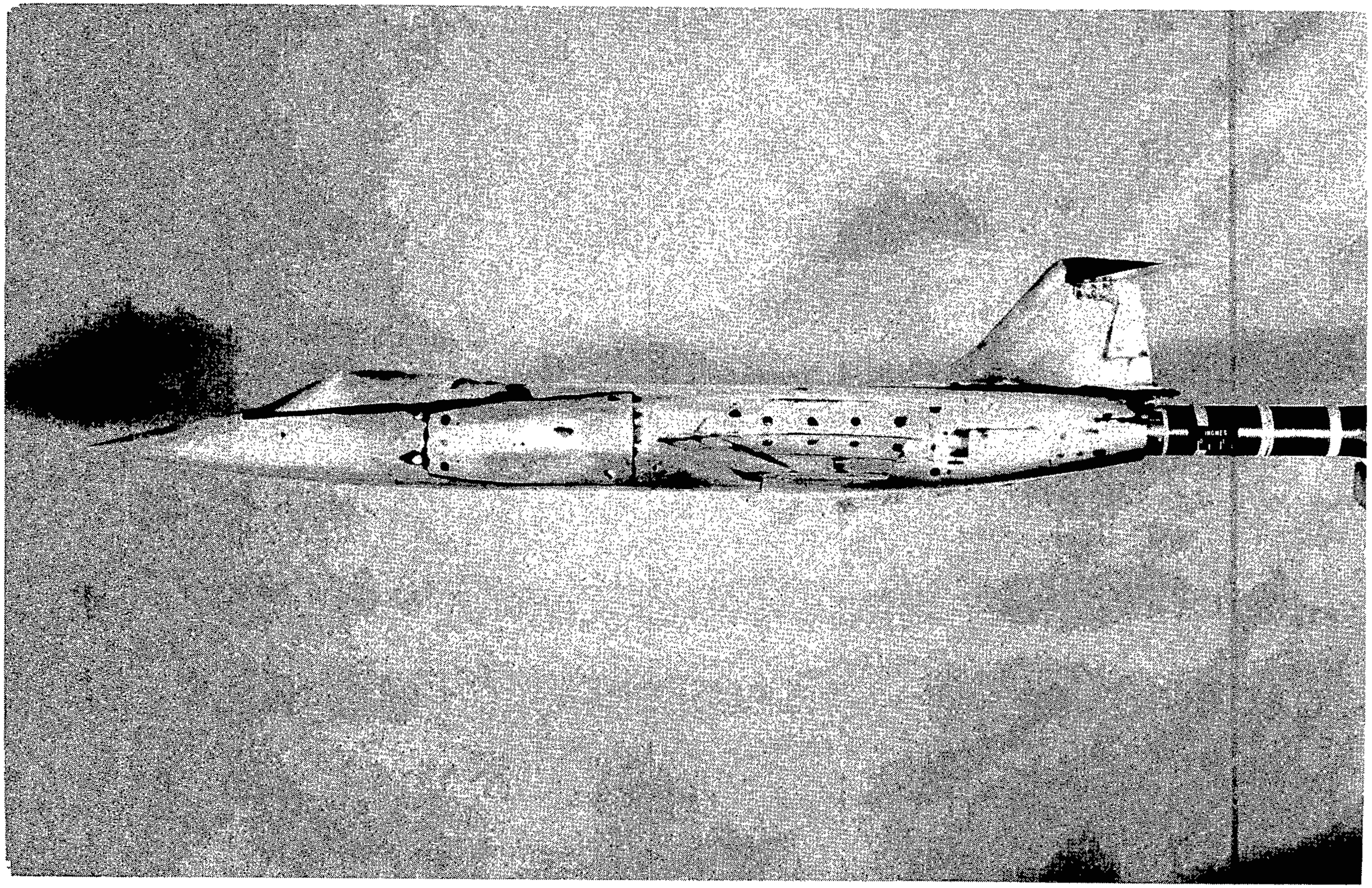
Figure 4.- Continued.



L-89748

(d) Four tip-mounted Falcons.

Figure 4.- Continued.



(e) Ventral fin. L-89746

Figure 4.- Concluded.

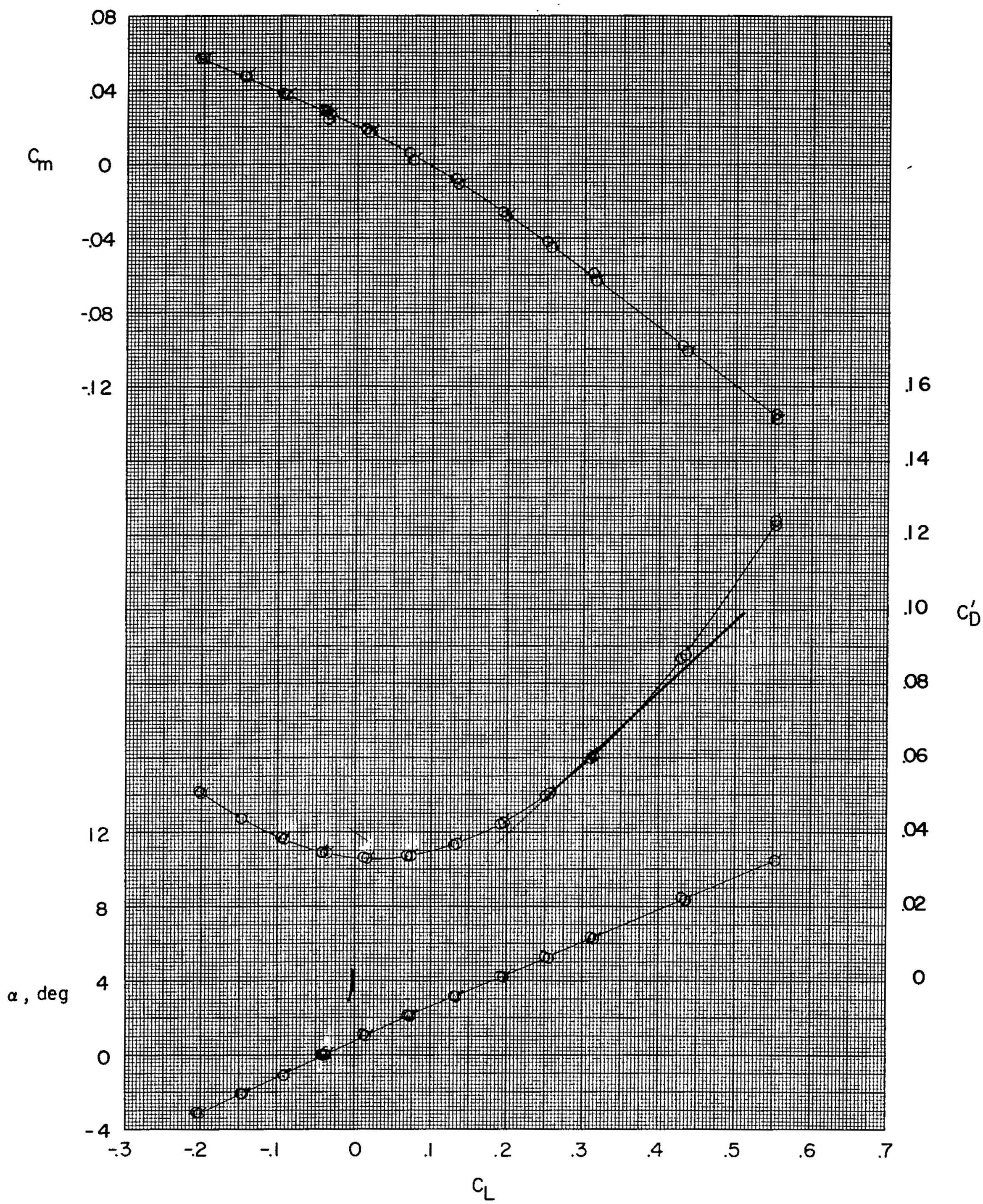
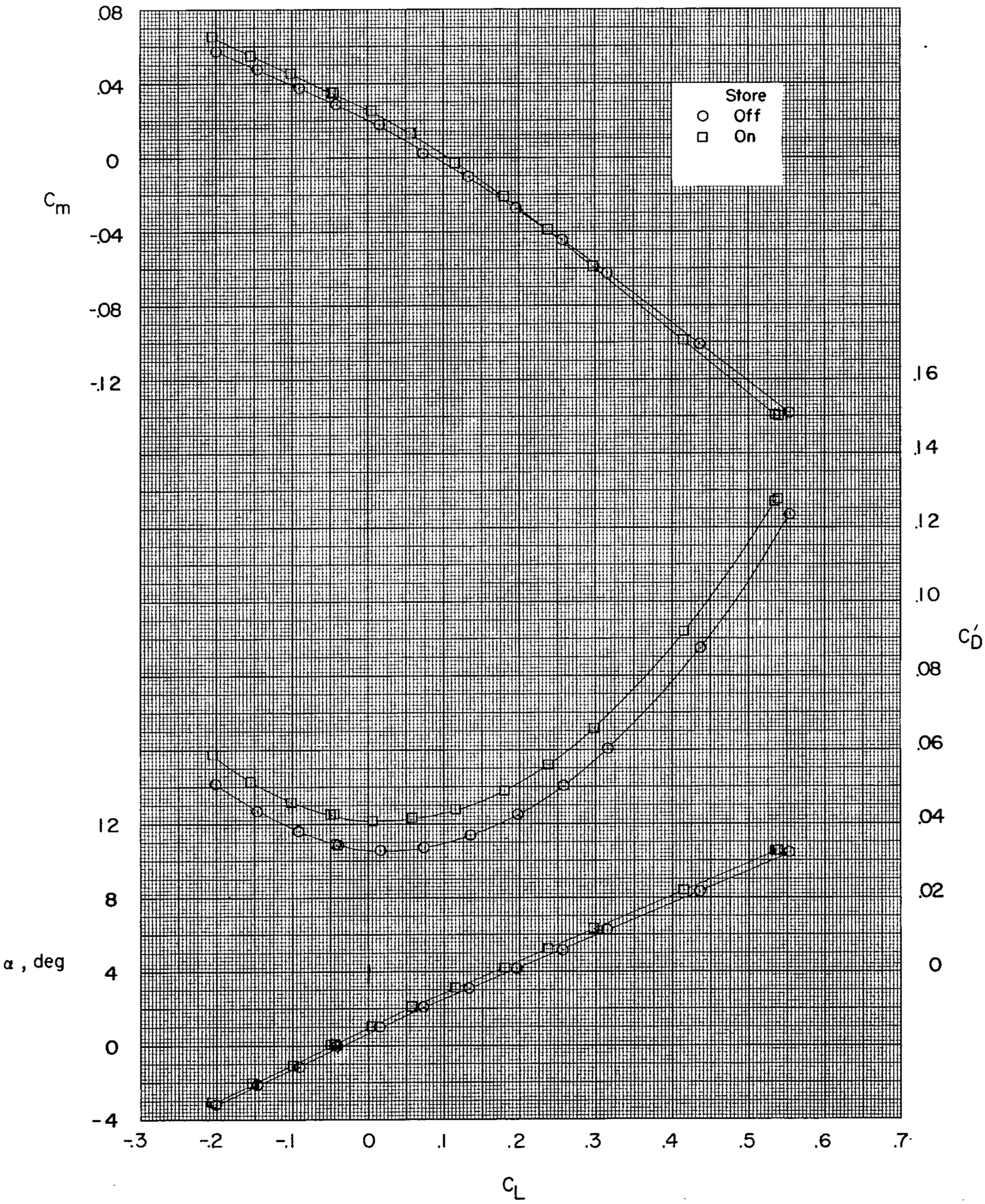
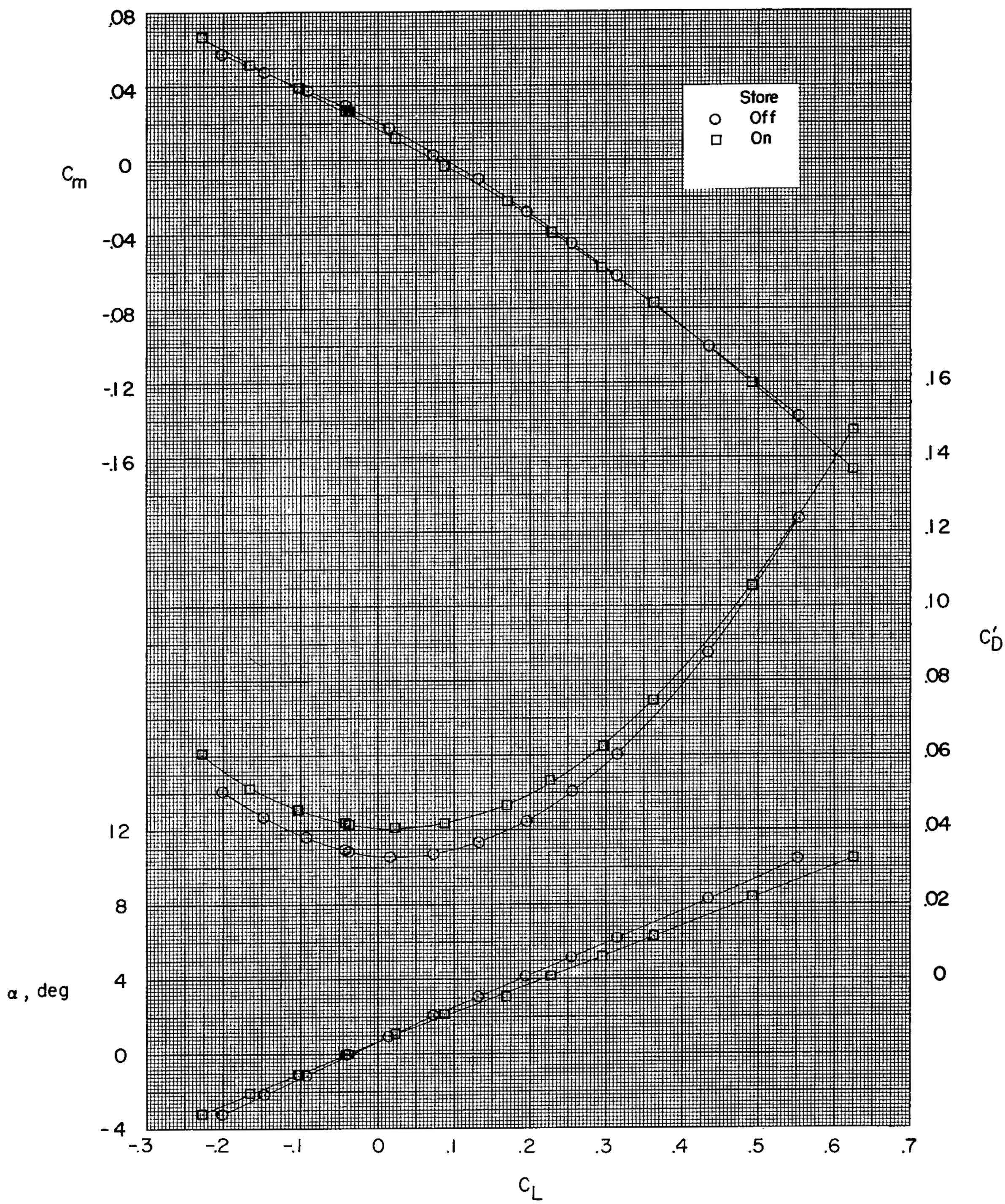


Figure 5.- Aerodynamic characteristics in pitch for basic configuration. $i_t = 0^{\circ}$. Flagged symbols are repeat points.



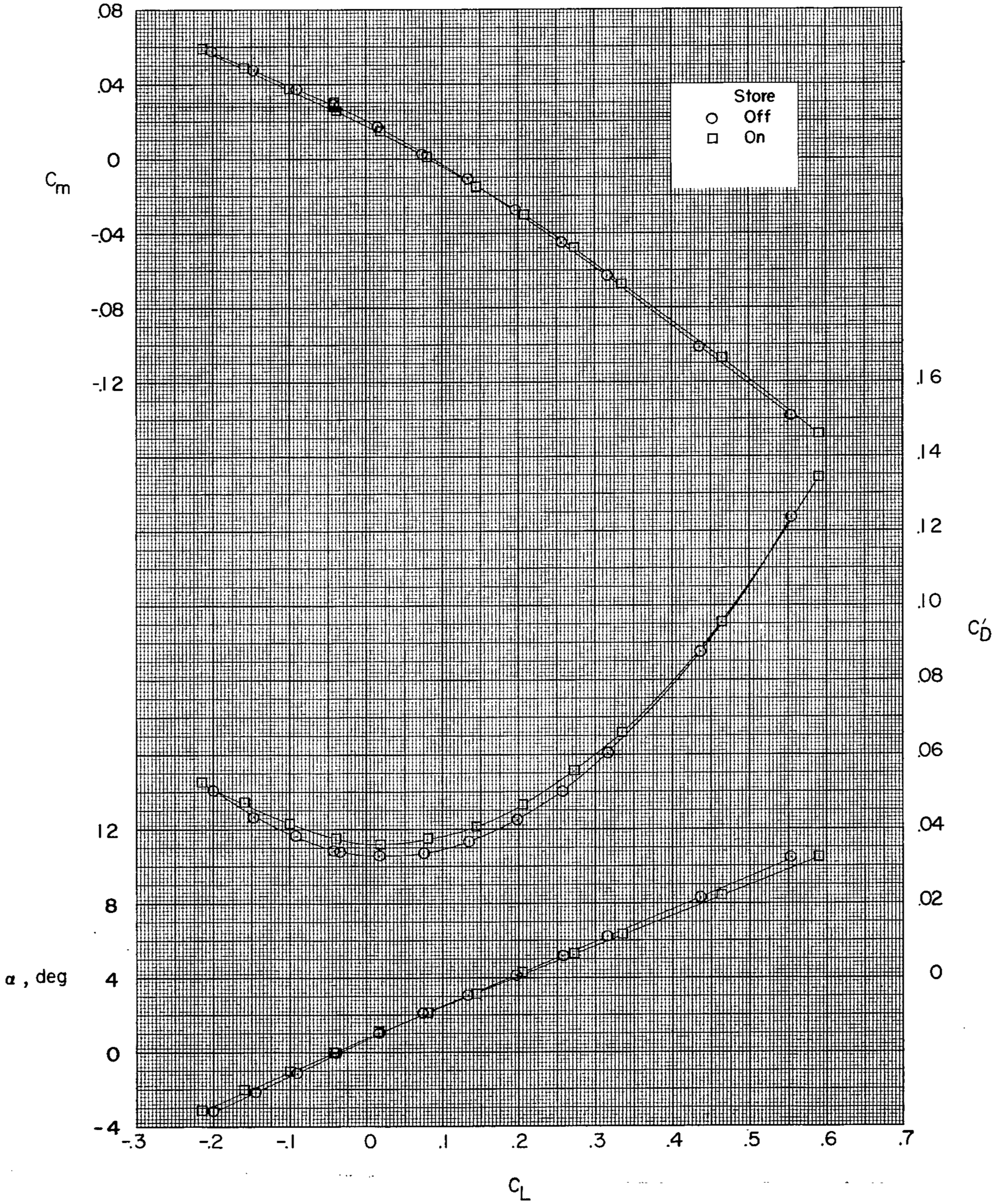
(a) Body store.

Figure 6.- Effect of various store installations on the aerodynamic characteristics in pitch. $i_t = 0^{\circ}$.



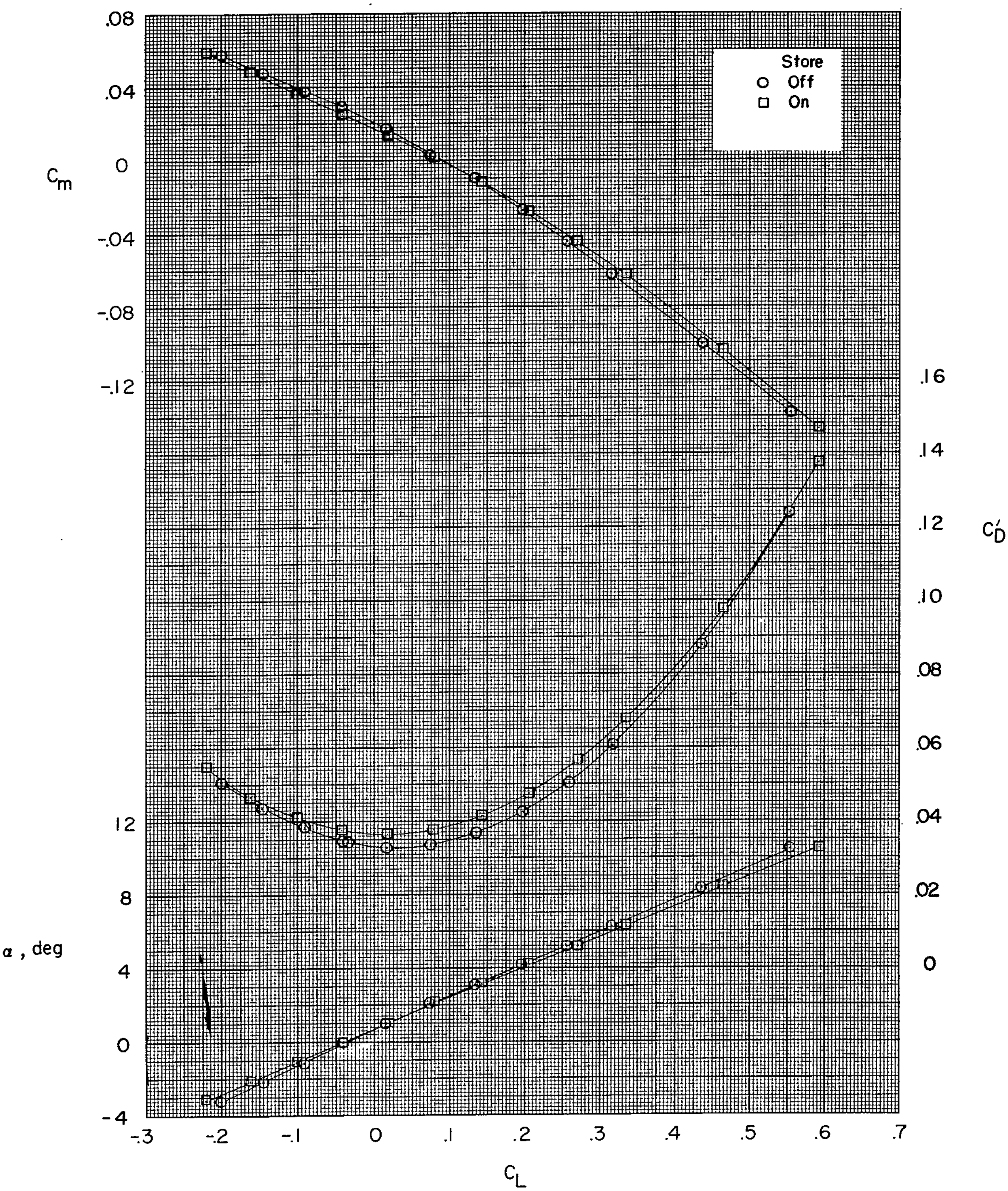
(b) Tip tanks.

Figure 6.- Continued.



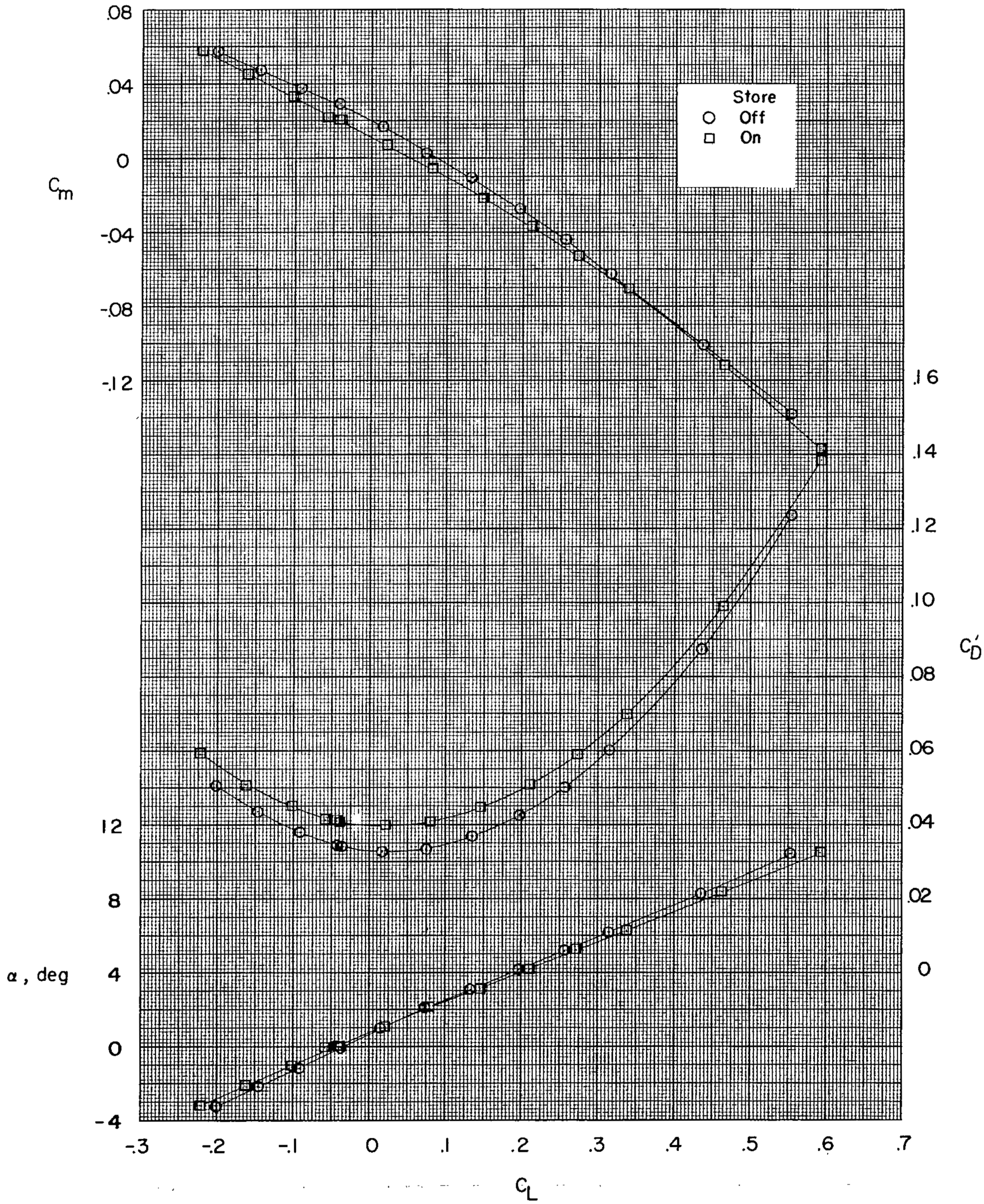
(c) Two tip-mounted Sidewinder missiles.

Figure 6.- Continued.



(d) Two tip-mounted Falcon missiles.

Figure 6.- Continued.



(e) Four tip-mounted Falcon missiles.

Figure 6.- Concluded.

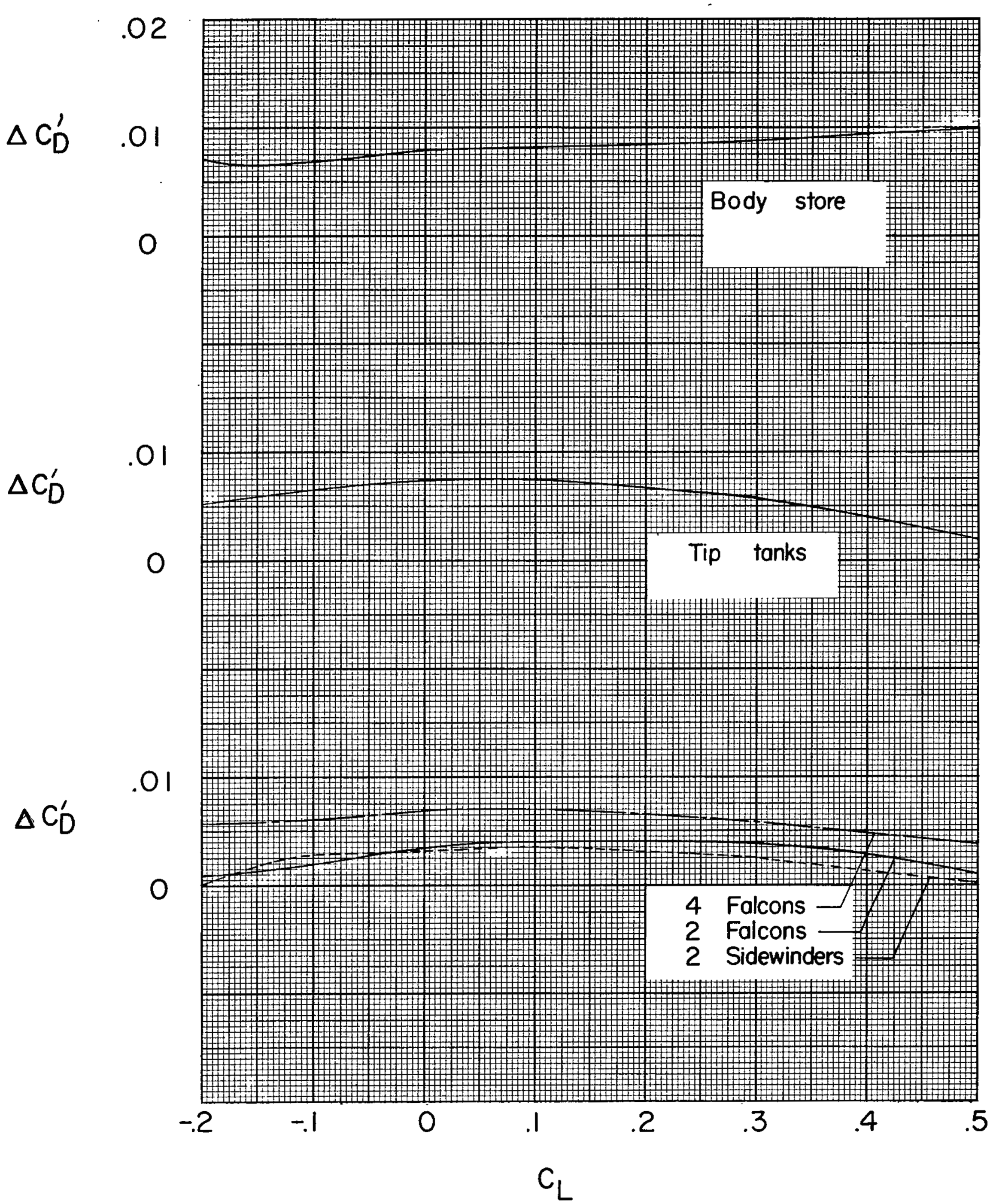


Figure 7.- Incremental drag resulting from various store installations. $i_t = 0^{\circ}$.

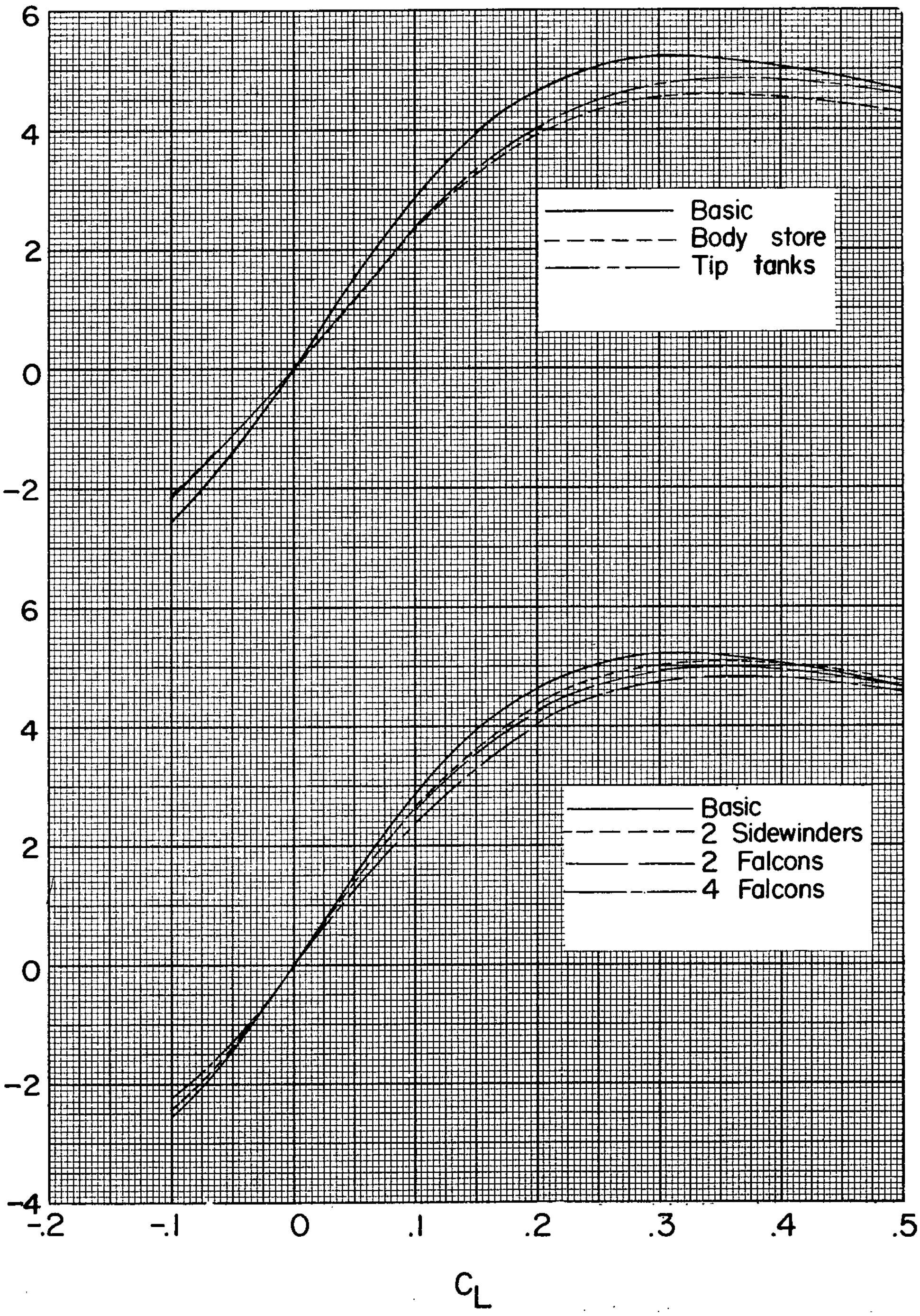


Figure 8.- Effect of various store installations on the lift-drag ratio. $i_t = 0^\circ$.

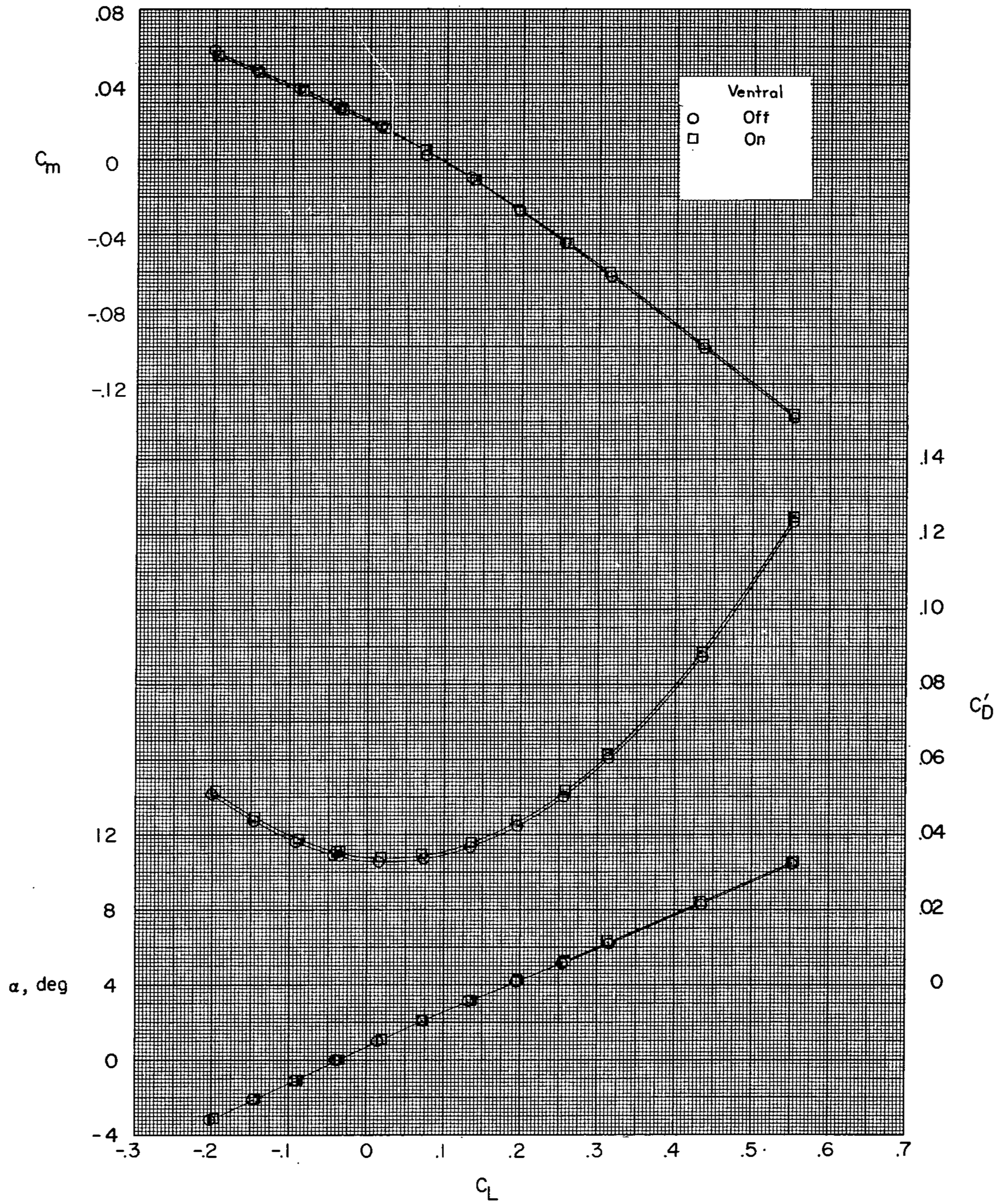


Figure 9.- Effect of ventral fin on the aerodynamic characteristics in pitch. $i_t = 0^{\circ}$.

[redacted]

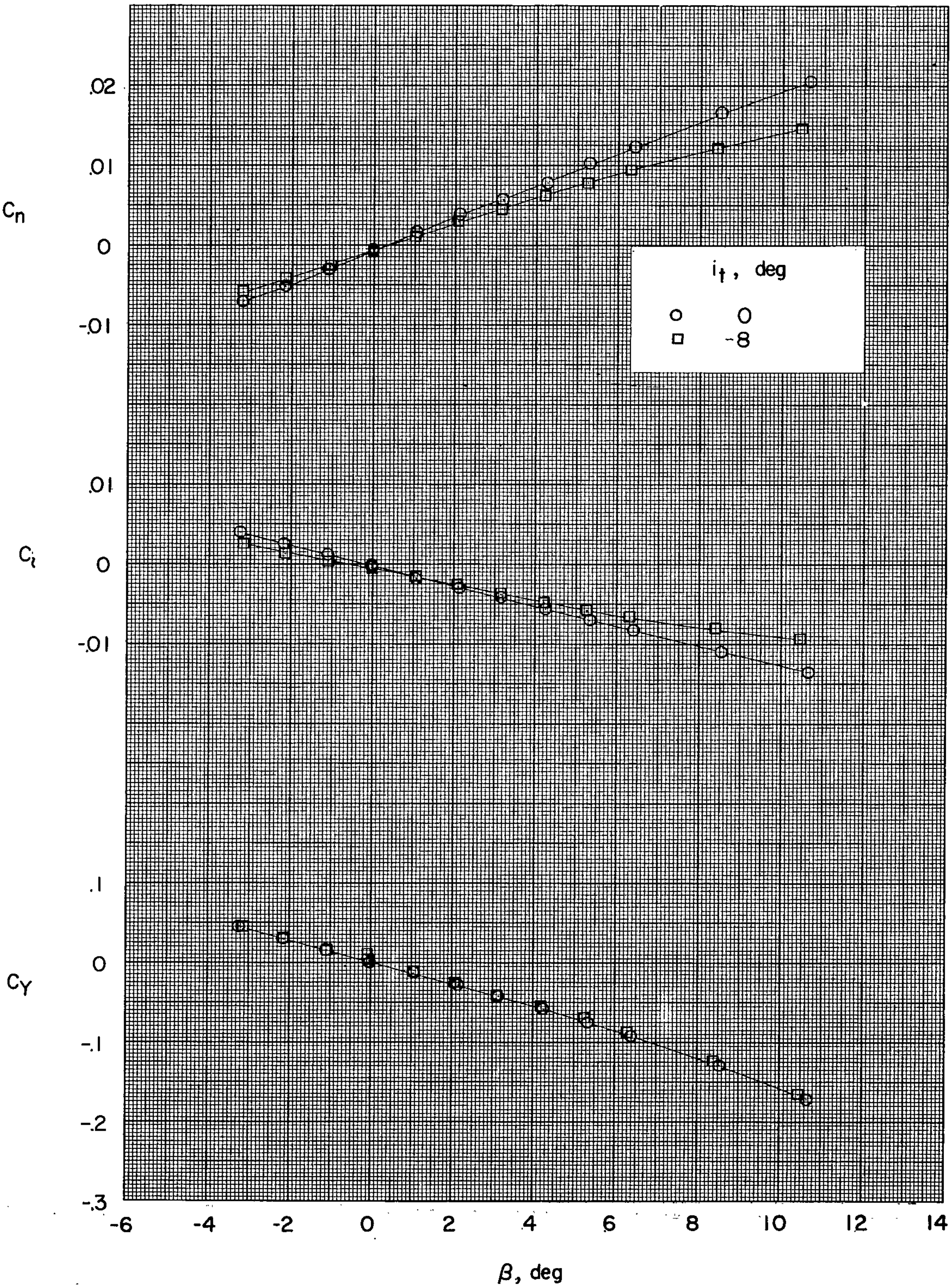


Figure 10.- Effect of stabilizer deflection on the aerodynamic characteristics in sideslip. $\alpha = 5.2^{\circ}$.

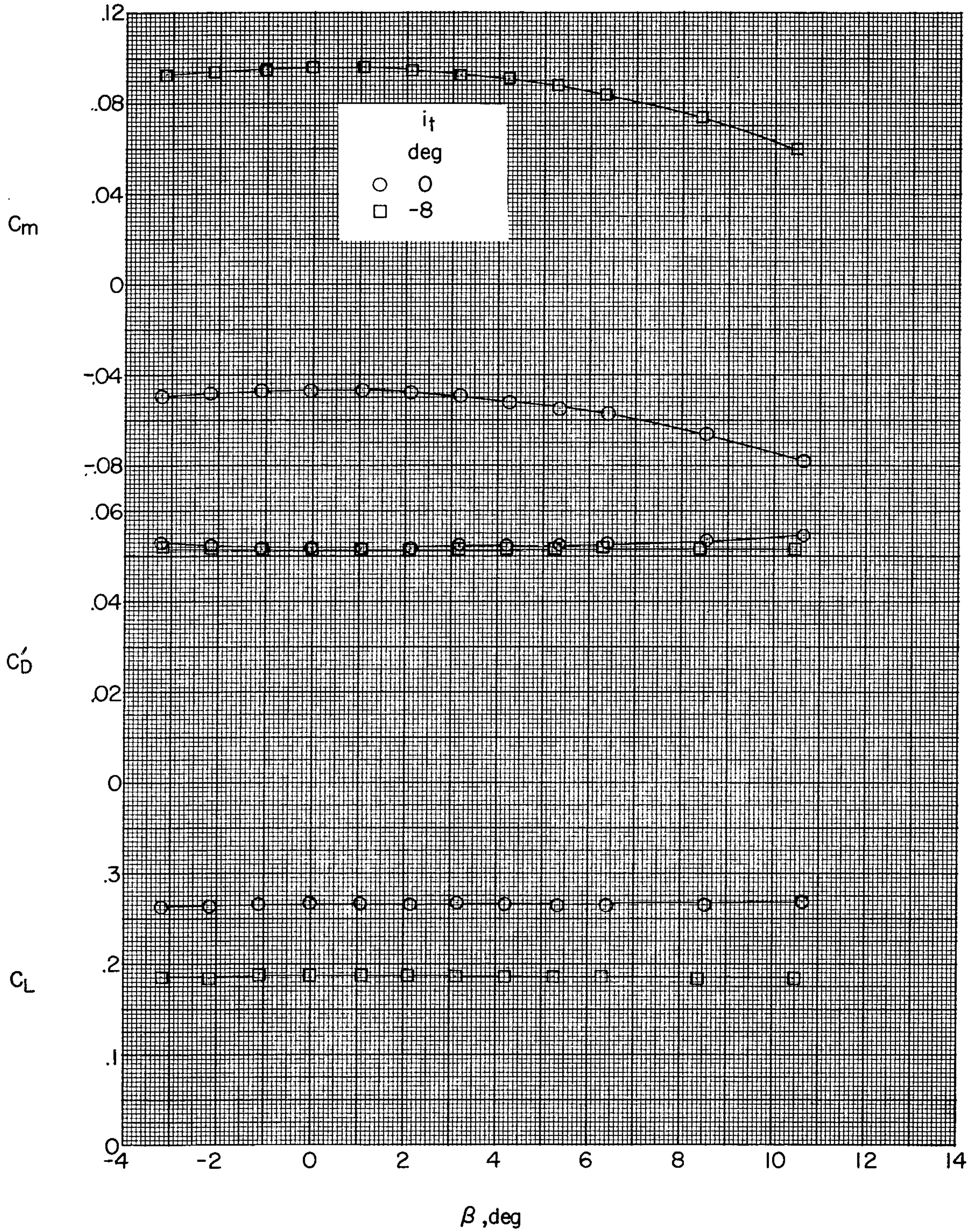


Figure 10.- Concluded.

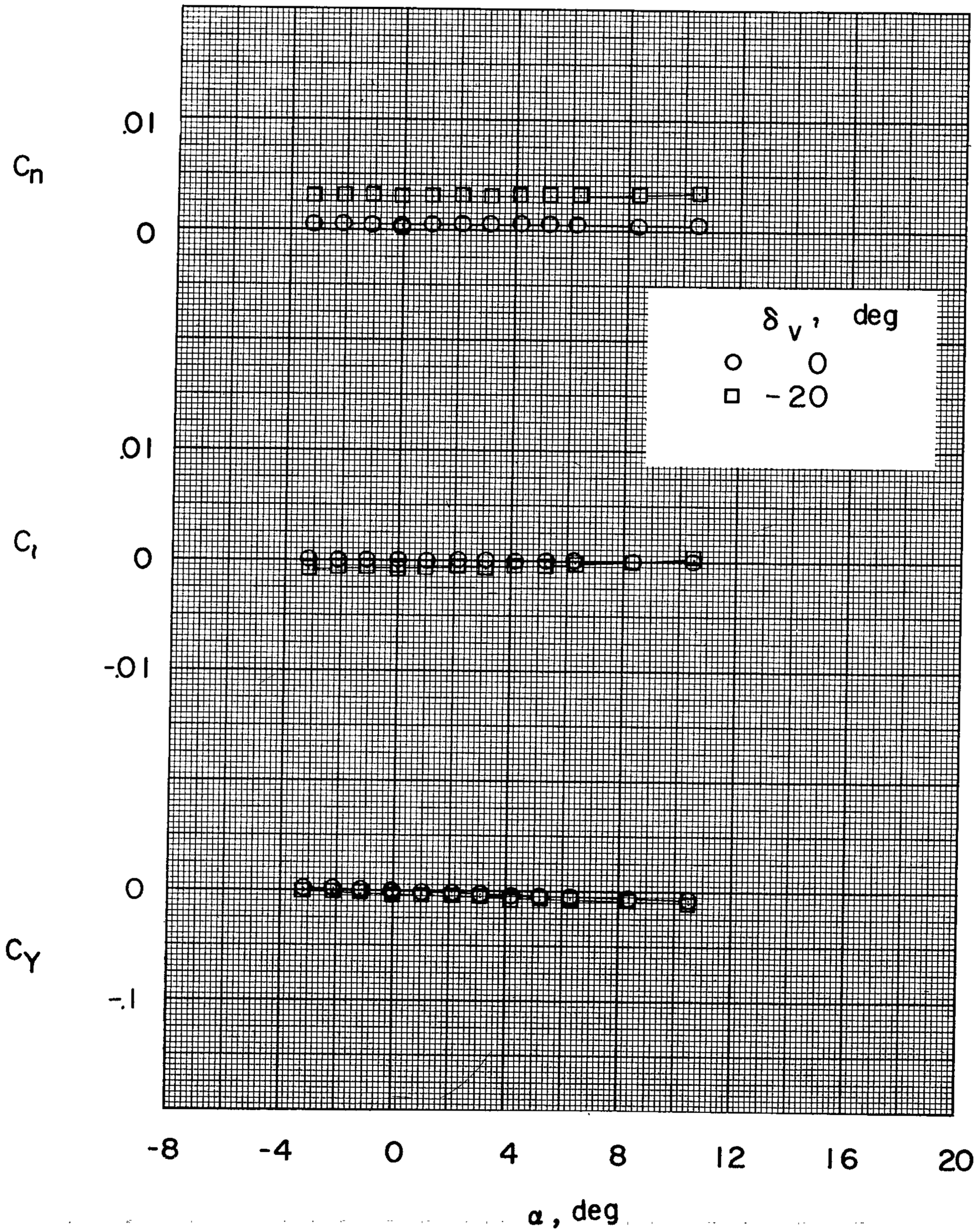


Figure 11.- Effect of yaw damper deflection on lateral characteristics in pitch. $i_t = 0^{\circ}$.